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- V. "Account of Spectroscopic Observations of the Eclipse of the Sun, August 18, 1868, in a letter addressed to the President of the Royal Society. By Captain C. T. HAIG, R.E. Communicated by the President. Received September 21, 1868.

Poona, 24th August, 1868.

MY DEAR SIR,—I hasten to send you an account of the observations I have fortunately been able to make at Beejapoor of the total eclipse on the 18th instant with one of the hand-spectroscopes sent out by the Royal Society in the care of Lieut. Herschel, R.E., not waiting to let my report be forwarded by Colonel Walker, R.E., my departmental superior, on account of the delay which would necessarily be caused thereby.

I may state at once that I observed the spectra of two red flames close to each other, and in their spectra two broad bright bands quite sharply defined, one rose-madder and the other light golden. These spectra were soon lost in the spectrum of the moon's edge just before emergence, which had also two well-defined bright bands (one green and one indigo) about a quarter the width of the bands in the spectra of the flames, this spectrum being again soon lost in the bright sunlight.

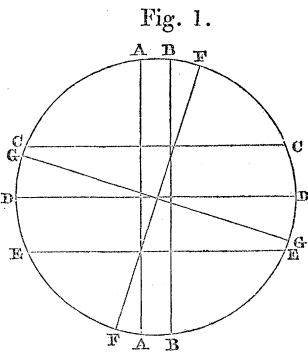
I will now proceed to give a somewhat detailed account of the observations, in which Captain Tanner, Bombay Staff Corps and of the Minar Survey (who, on my earnest solicitation, accompanied me), and Mr. Kero Laxuman, Professor of Mathematics in the Deccan College, took part, and during which Mr. Hunter, Bombay Civil Service, and Dr. Kielhorn, Professor of Sanskrit in the Deccan College, were present as non-professional observers.

Our instrumental equipment consisted as follows :—Mr. Kero Laxuman brought an ordinary pedestal-telescope of $2\frac{1}{4}$ -inch aperture and 36 inches focal length by Horne and Thornthwaite, which he temporarily mounted on a stand equatorially; and he had a scale fitted inside a 60-power eyepiece, which, however, he was unfortunately not able to use, on account of a fall which his instrument sustained from being blown down by the high wind; he therefore had to use another eyepiece of power 70, not furnished with a scale. He also had a pocket chronometer beating five times to two seconds, by Arnold and Dent.

Captain Tanner had an Everest theodolite by Troughton and Simms, having a remarkably good telescope, $1\frac{7}{8}$ -inch aperture and 18 inches focal length, and an eyepiece of power 46.

I had one of the Royal Society's small hand-spectroscopes, and a small 6-inch transit theodolite by Troughton and Simms, the cap of the object-glass of which I had cut so as to receive the prism-cap of the spectroscope, and had fitted one to the other, so that I could at once shift the prism-cap from its own telescope to that of the theodolite, and *vice versâ*.

I had also a black frame about 2 feet long by 1 foot high with a slit in the centre, the width of which was regulated by turning a black excentric cylinder. This I had previously used in observing the lines in the solar and other common spectra, and I placed it 10 feet from the theodolite (the shortest distance the telescope could focus); and close at the back of it I placed a heliotrope held by a Survey Signaller, intending, if opportunity offered, to examine the lines in the spectrum of the corona. In the diaphragm of the theodolite-telescope I had a system of wires (shown by diagram below), which I had intended for assistance in general observations of the flames, in case I should find that I could make no satisfactory spectrum-observations, which, from the absence of any slit arrangement in the spectroscope, I was rather inclined to anticipate. The wires AA, BB were vertical, CC, DD, EE horizontal, FF the direction of the moon's path at the middle of the eclipse, and GG perpendicular to FF. This system gave so many fixed distances and points that I thought it would be useful both in estimating the position and the height of the flames. However, its utility was not put to the test; for the little time I had was given to the spectroscope. I also had an eight-day mean-time chronometer beating half-seconds, by Baker.



The sky in the early morning of the 18th was very cloudy, so that our hopes of success were very low; but as it afterwards brightened up for a while rather suddenly, we were somewhat encouraged to hope for a similar brightening during part of the eclipse. Soon, however, at about 7 o'clock, it darkened again, and remained so till after the total phase was over, occasional openings in the nimbi giving us glimpses of the sun through the cirrocumuli which were floating very high up. At 7 o'clock we had reached our station of observation, which was on a large solid tower called the Uparī Būrj, 67 feet high and about 60 feet diameter (on the top were two guns, one of which was 31 feet long)—one of the many ruins of the city, and a most favourable position from which to observe the phenomena of the eclipse and the general aspect of the surrounding country. On account of the prevailing very high wind, we planted our instruments on and near the top of the external stone staircase so as just to be protected by the tower from the wind. Mr. Kero Laxuman at first set up his telescope on the top of the tower; but it was blown down, as I have previously mentioned. This accident much interfered with the carrying out of our preconceived plan of observation, which was as follows.

Mr. Kero Laxuman and Captain Tanner were to take the times of first and last contact, the latter by observing the actual occurrences, the former

by measuring several lengths of the common chord soon after first and before last contact, with the aid of the scale in his 60-power eyepiece and noting the times. Captain Tanner (an expert delineator) was, during totality, to take command of Mr. Kero Laxuman's telescope, measuring the heights of the flames at times which would be recorded by Mr. Kero Laxuman, whose whole attention during totality was to be given to recording the times of occurrence of any phenomena that he, or either of us, might observe. Captain Tanner was also to make rapid sketches of all he saw, and I was to confine myself to spectrum-observations.

Unfortunately, contact was not observed until about fifty seconds after the commencement, when Captain Tanner at once made a sketch of the obscuration, Mr. Kero Laxuman recording the time. The sketch made the common chord equal to 3' at 7^h 51^m 17^s local time, giving 7^h 50^m 17^s as the time of first contact. Captain Tanner afterwards tested that sketch by noting the time before last contact, when the chord appeared of a similar length, which gave an interval of 45^s; so that, taking the mean between the original estimate and its verification, we have 7^h 50^m 24^s.5 as the time of first contact.

While the obscuration was increasing, Captain Tanner, during the few peeps we got at the eclipse, made drawings of the sun's spots, and sketched the mountains on the moon's edge, of which there were two plainly visible even with my small theodolite. The darkness increased very slowly till just before totality, when the increase was very rapid and sudden, and a general spontaneous exclamation "Oh!" from all of us gave Mr. Kero Laxuman the time of beginning of totality, which he recorded as 9^h 1^m 49^s. The eclipse was at that time completely shut out from our view by the clouds—nimbi low down being carried past by the high wind; we therefore felt at leisure to make our remarks on the degree of the darkness, which we were surprised to find so far from total. We could easily write, read our writing, and read the seconds of our watches without the aid of artificial light. We were all lamenting our misfortune in not being able to observe the eclipse, and had given up all hope of witnessing the phenomena we had come so far to see, and Captain Tanner had just noticed the faint reappearance of light in the west, when, contrary to all expectation, and to our intense satisfaction, a sudden opening in the nimbi showed us the eclipse through the cirrocumuli. We were each at our telescopes in an instant. I immediately saw through the naked telescope of the small theodolite that red flames were visible, and at once pointed the spectroscope, using the theodolite-telescope as a rest. Very fortunately I directed the spectroscope with its "refracting edge" tangent to the moon where two red flames were protruding, separated from each other by a small interval; so that their spectra, which were identical, were extended over the dark background of the moon's disk, and stood out in most marked and brilliant contrast with the feeble but continuous spectrum of the corona; and in

their spectrum there were the two broad bright bands I have above described. Most fortunately also these red flames were on that part of the sun which first reappeared ; so that just before or just *at* emergence there appeared at the very part I was intently observing one brilliant wide spectrum with the green and indigo bands before described, remaining visible for an interval just long enough to enable me to make quite sure of the position of the bands, which were then obliterated by the bright light of the sun. Of course, observing with the spectroscope alone it would have been impossible to say whether the spectrum with the green and indigo bands appeared just before or just after emergence ; but I think it must have been just before, because Captain Tanner called out when totality was over ; and I immediately remarked that I thought he was rather late, but he was quite confident about the accuracy of his observation. What struck me as being very remarkable was the circumstance, that though the light of the red flames was to the naked eye so feeble as to be outshone to extinction by that of the corona, nevertheless, when viewed with the spectroscope, the spectrum of the corona was very weak, and that of the flames remarkably brilliant. On the first glimpse of the eclipse, before looking through the telescope, the corona appeared so bright, that it gave me the momentary impression (as it did to Captain Tanner) of its being an annular eclipse. We are divided in our estimate of the length of the interval during which we observed the totality. It appeared to me very short—so much so, that when it was over I was quite taken by surprise to hear that both Captain Tanner and Mr. Kero Laxuman had taken sketches of the flames ; and their sketches, both as to position and structure, were, with one slight exception, remarkably coincident. From the time of my first pointing the spectroscope to the bursting out of the sun's light I never once withdrew my eye, though it had been my intention to shift the prism-cap on to the telescope of the theodolite as soon as I should have carefully noted the spectrum of the flames ; but while I was intently gazing on the two bright bands to impress their colour well on my memory, the new spectrum of the moon's edge appeared, so that I was under the impression that the length of the time of observation was very short. On the other hand, Captain Tanner, judging from the amount of work he did in the time, estimated it at a minute. Mr. Kero Laxuman estimated it at 40 or 45 seconds. Immediately after the totality was over we all three made rough notes of our observations ; and Captain Tanner's and Mr. Kero Laxuman's notes agree together wonderfully in their description of the structure of the flames.

The accompanying rough sketch was made by Captain Tanner, who had not the means of making a more finished drawing. The sketch shows the *actual* appearance of the eclipse. It was observed by Captain Tanner wholly inverted, and by Mr. Kero Laxuman (who used a diagonal eyepiece) inverted vertically but not laterally. Captain Tanner and Mr. Kero Laxu-

man only differed in their position of the small flame *c*, the former placing it to the right, the latter at a similar distance on the left of the flames *b*; but Captain Tanner at once yielded his conviction to that of Mr. Kero Laxuman, which, therefore, we accepted as most likely to be true. The spectrum of *c* was not observed by me at all. I therefore think it could only have appeared simultaneously with the bright spectrum of the moon's edge. I so held the spectroscope that I could not see the spectrum of the flame *a*.

The following is an extract from Captain Tanner's notes, taken almost immediately after the eclipse:—"I at first saw three prominences—one long curved pointed tongue, and two close together, straight but flat-topped, about two-thirds the height of the former. They were of a rose-madder colour, and were decidedly more like flames than anything else, not only in their general appearance and colour, but by their being composed of smaller tongues of flame parallel (or nearly so) to the general axis of the flame, so that they had a streaky appearance and a ragged edge. At the first glance, when the sun was somewhat obscured by clouds, I thought they were homogeneous and had hard edges; but this idea was at once dispelled when the clouds cleared off. The two protuberances, which were close together, were not, as far as I could see, joined by any smaller shots of flame. I afterwards observed one small protuberance, and marked the position of it in my sketch. I did not observe that it was streaky, as the others were—perhaps on account of its being so small, and perhaps because I had not sufficient time to examine it properly. As regards the corona, when we first began to see the eclipse through the clouds, I was under the impression that the eclipse, instead of being total, was only annular, so bright was the corona near the moon's limb. I could not detect any irregularities in the structure of the corona, but the light appeared to be gradually shaded off all round."

Captain Tanner also says, "The most careless observer would notice the streaks of which the flames *b* were composed; but it required more careful inspection to determine the streaky nature of the flame *a*."

The following is from Mr. Kero Laxuman's notes:—"The protuberance *a* appeared like a red flaming torch, width $\frac{1}{2}$ a minute, height about 2 minutes, colour dark red, lines stretched over a less-red ground. The direction not perpendicular to the edge of the moon, but making an angle of 60° with it. Those marked *b* were broader and almost as high as *a*, but not pointed. They appeared to expand a little at the vertex. They were also streaked by several dark-red lines. That marked *c* appeared semicircular, with a breadth of about $\frac{1}{2}$ a minute. The flame *a* was visible for about 2 minutes after the end of totality; and had there been no clouds, I think it could have been seen longer."

Both Captain Tanner and Mr. Kero Laxuman also agreed in describing the form of the red flames *b* as somewhat similar to hands with fingers slightly separated.

There is a curious coincidence which I may here mention, though I imagine it can only be regarded as purely fortuitous, viz. that the flames were almost exactly opposite the spots on the sun's disk.

On the afternoon of the 18th, Captain Tanner and I went to Moolwar, eighteen miles south of Beejapoor, where the German astronomers had put up their instruments. We there learnt that they had only seen the eclipse for less than 5 seconds during totality, and that through an upper stratum of clouds which rendered photometric observations impracticable; but we were surprised to hear that neither a spectroscope nor a polariscope was attached to either of their equatorial telescopes at the time of visibility, but that both the observers with these instruments were intent on measuring the heights of the flames. They determined the normal height of flame *a* to be 3 minutes; but as they must have seen it at an earlier phase than Captain Tanner and Mr. Kero Laxuman, it would appear slightly longer to them than to us.

It is very curious how the darkness during totality seems to have differed in degree in different places. At Beejapoor we were told that down below in the town the darkness was so great that it was not possible to see one's own hand. We thought this account might be an exaggeration; but we afterwards learnt that at Moolwar a gentleman dropped part of an eye-piece of a telescope, and that it was not possible to find it even by placing the eye close to the ground, until after the end of totality.

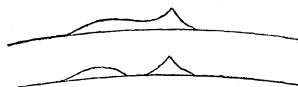
We have not had time during our continual travelling to compute the elements of the eclipse for Beejapoor for ourselves; and it might have been waste of time to have done so before we started on our journey, for we were uncertain of our being able to get so far south as Beejapoor; but I give below a statement of elements for Beejapoor as computed by Mr. Pogson, astronomer at Madras, and published in the 'Times of India,' and with it the times as observed or estimated by us.

	Mr. Pogson's elements.	Our elements.	Remarks.
First contact	h m s 7 50 54	h m s 7 50 25	Mean of two estimates.
Beginning of totality	9 2 9	9 1 49	Approximate.
End of totality	9 7 21	9 6 59	Actually observed.
Last contact	10 28 44	10 28 14	" "
Angle from } first contact... vertex of... } last contact...	1° right. 173° right.	At vertex. 165° right.	Approximate.

There was a difference in our times of last contact. Mr. Kero Laxuman made it at 10^h 28^m 9^s; I made it 10^h 28^m 14^s, and Captain Tanner 10^h 28^m 17^s. I was observing with the little theodolite, and distinctly saw the moon's

limb after Mr. Kero Laxuman had called out ; so I attributed his error to the vibration of his telescope caused by the wind. Capt. Tanner observed, I believe, *the* last contact ; but, strange to say, the point of the moon which made last contact was a mountain-peak of this

shape ; Capt. Tanner would make it thus,



dividing the mountain into two hills ; and he says I was a second too soon in my observation, which was of the spherical last contact ; and perhaps he was right, as he had a better telescope than I had. His observation at $10^h 28^m 17^s$ was the time of the *peak* leaving the sun's limb ; so that he and I differ only by 1 second, as to whether the spherical last contact occurred at $10^h 28^m 14^s$ or $10^h 28^m 15^s$.

I sent a native assistant to Moolwar (the station selected by the German astronomers) to take observations with a barometer, and with wet-, dry-, and black-bulb thermometers, continuously for some days before and after the eclipse, but I anticipate no interesting results (from the rough glance I took at the records on the evening of the 18th). The atmosphere was during the time in a very disturbed state.

Mr. Chambers, of the Bombay Observatory, went to a village called Mongoli, about six miles east of Moolwar, with the intention of observing the eclipse ; but he was disappointed, for it was completely obscured by clouds during the whole of the total phase.

I have not yet heard what success has attended Lieuts. Herschel and Campbell with the spectroscope and polariscope at Jamkhandi, so that I am quite ignorant of the value of our observations ; but I trust that even should other observers have succeeded in contributing to physics more definite information, ours may at least be valuable as corroborative evidence.

I am, dear Sir,

Yours faithfully,

C. T. HAIG,

Captain Royal Engineers.

General Sabine, R.A., P.R.S.

EXPLANATION OF THE PLATE.

Fig. 1 represents the total eclipse as it appeared during the last 20 seconds of the total phase.

Fig. 2. Red prominences, drawn to larger scale, and showing the streaked structure of *a* and the radiating thicker lines composing the double prominence at *b*. (*Note.* A light-red colour showed itself between these streaks, which gave the prominences a greater appearance of solidity.) *c*₂, small red prominences as noted by Kero Laxuman ; *c*₁, the same as noted by me (*c* appeared just at the end of totality). The height of *a* was a little over 2', *b* about 1' 40'' ; *c* may have been 0' 20''.

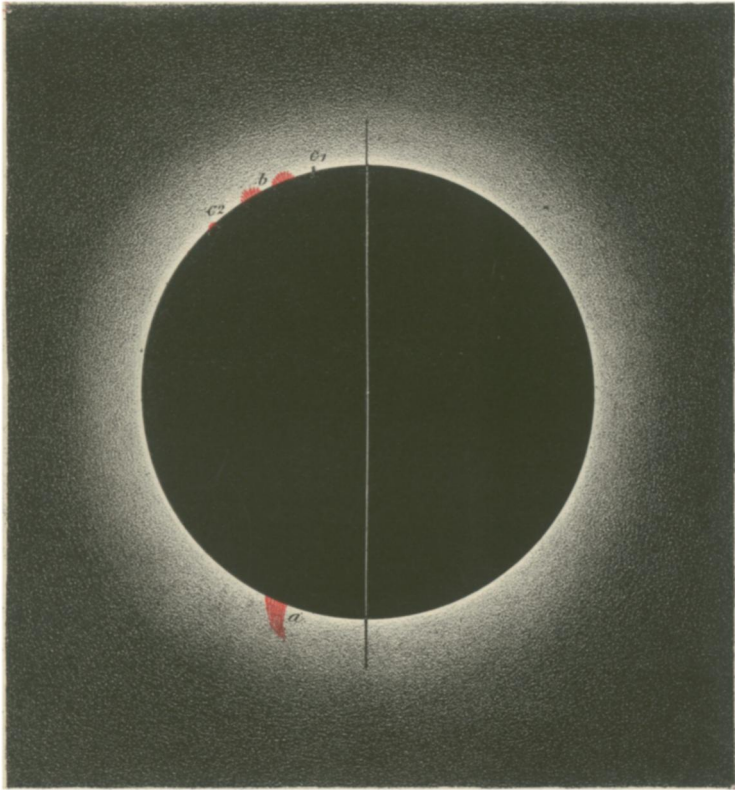


Fig 1.

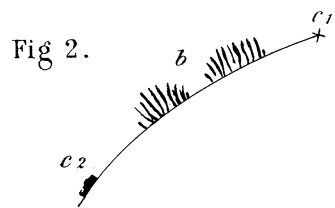


Fig 2.